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(54) **ROBOT CENTER-OF-GRAVITY DISPLAY  
DEVICE, ROBOT CONTROL DEVICE, AND  
ROBOT SIMULATION DEVICE**

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(Continued)

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CPC ..... **G01M 1/122** (2013.01); **B25J 9/1671**  
(2013.01); **B25J 13/06** (2013.01);  
(Continued)

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Y10S 901/02; Y10S 901/16; Y10S 901/48  
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(56) **References Cited**

U.S. PATENT DOCUMENTS

5,214,749 A \* 5/1993 Brown ..... B25J 9/1643  
700/260

5,325,467 A 6/1994 Torii et al.  
(Continued)

FOREIGN PATENT DOCUMENTS

EP 0484551 A1 5/1992  
EP 2070662 A1 6/2009

(Continued)

OTHER PUBLICATIONS

Japanese Office Action dated Apr. 24, 2018 in corresponding Japan  
Application No. 2016-137349; 9 pgs.

(Continued)

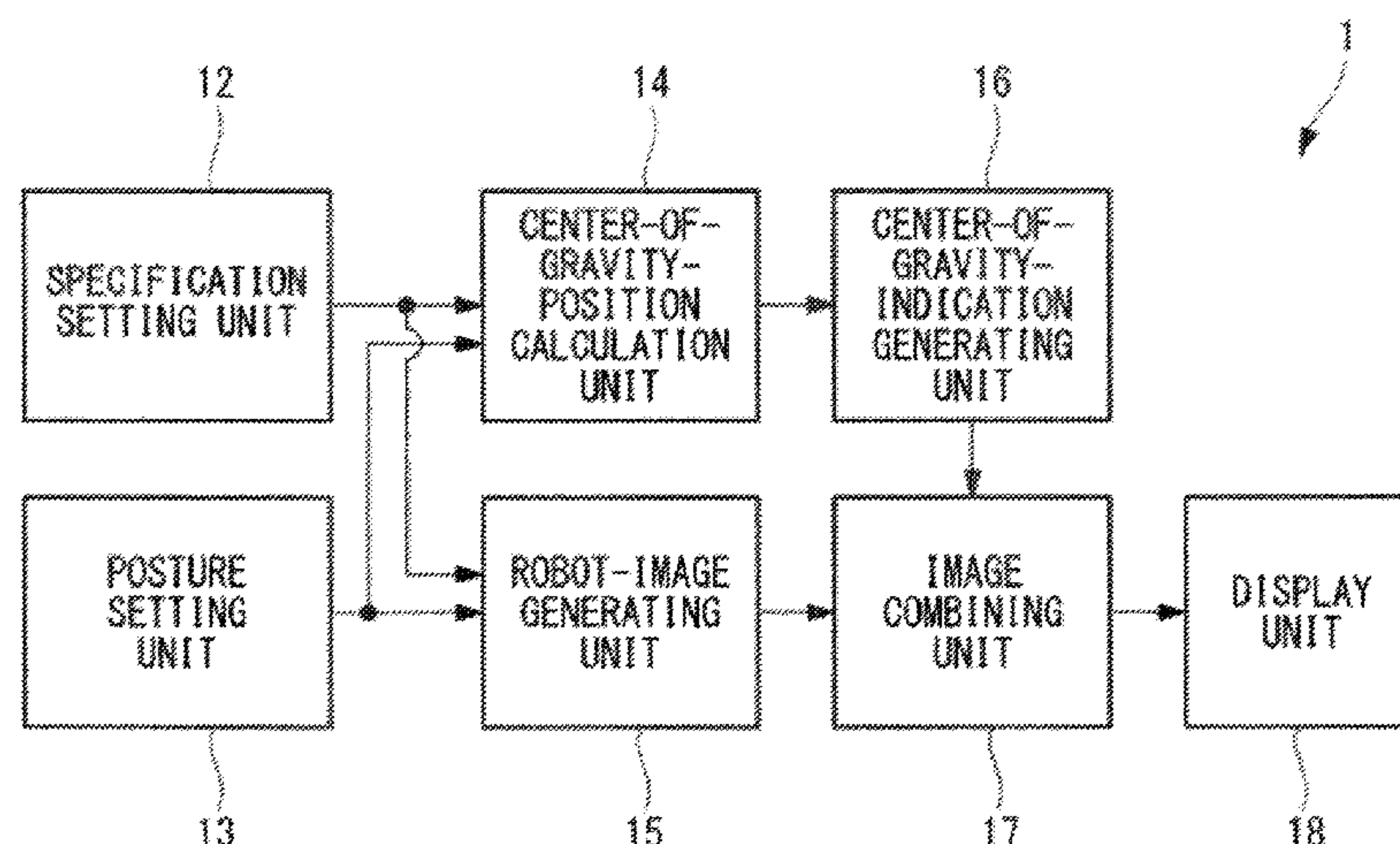
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(57) **ABSTRACT**

Provided is a robot center-of-gravity display device including: a specification setting unit that sets specifications including the weights, center-of-gravity positions, and dimensions of components of respective shafts; a posture setting unit that sets position information of the respective shafts; a robot-image generating unit that generates a three-dimensional model image of the robot in a state where the respective shafts are located at the positions indicated by the position information, based on the set position information of the respective shafts and the specifications of the components; a center-of-gravity-position calculation unit that calculates the center-of-gravity position of the overall robot, based on the set position information of the respective shafts and the specifications of the components; an image combining unit that superimposes an indication showing the center of gravity of the overall robot on the three-dimensional model image at the calculated center-of-gravity position; and a display unit that displays the generated image.

**6 Claims, 7 Drawing Sheets**



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FOREIGN PATENT DOCUMENTS

## U.S. PATENT DOCUMENTS

JP	S62-65190	U	4/1987
JP	H04-30203	A	2/1992
JP	10-138187	A	5/1998
JP	2001-277158	A	10/2001
JP	2003-196323	A	7/2003
JP	2008-62330	A	3/2008
JP	2008-207331	A	9/2008
JP	2016-49616	A	4/2016

Search Report dated Apr. 12, 2018 in corresponding Japan Application No. 2016-137349; 13 pgs.

\* cited by examiner

FIG. 1

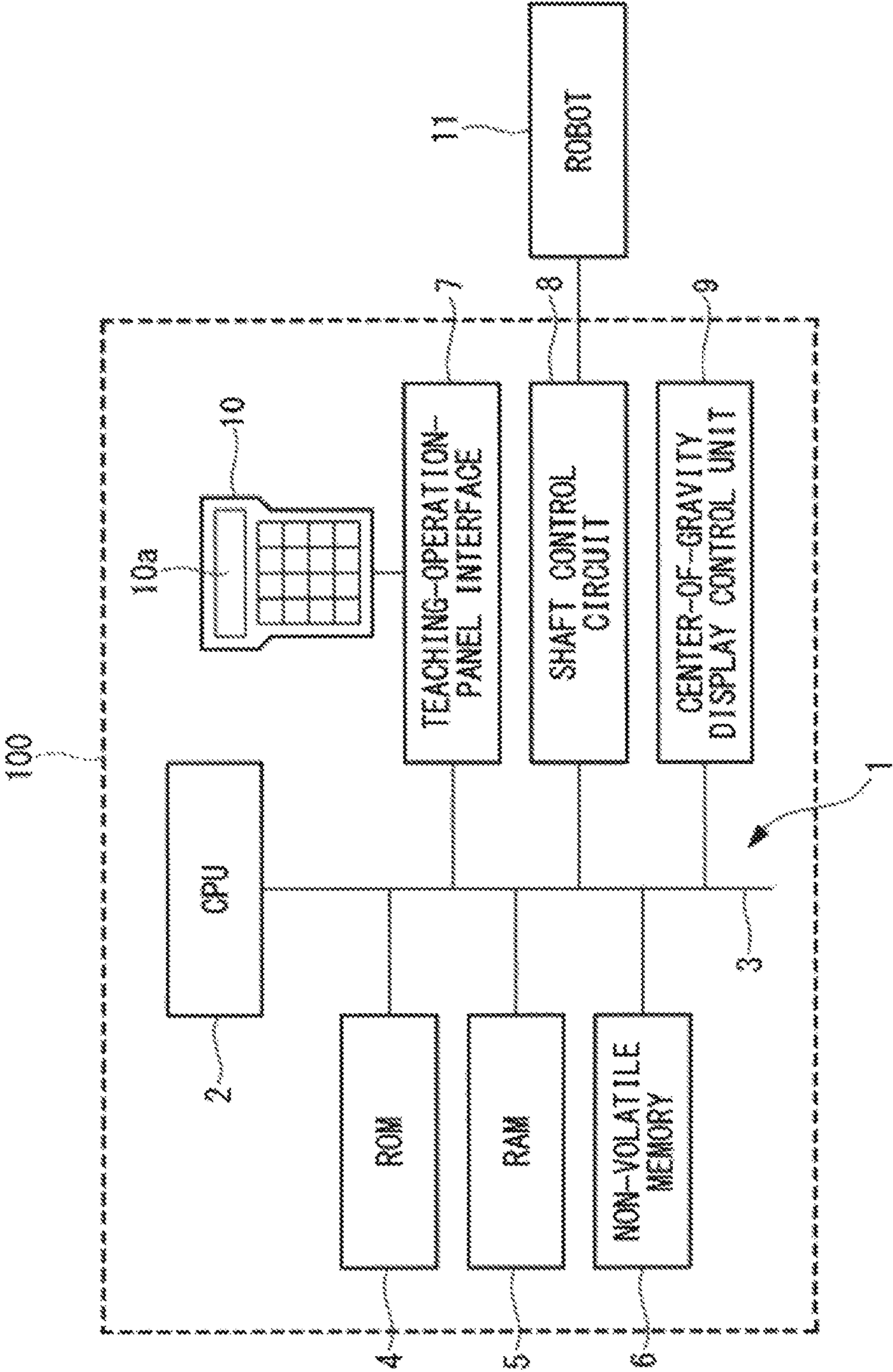




FIG. 2

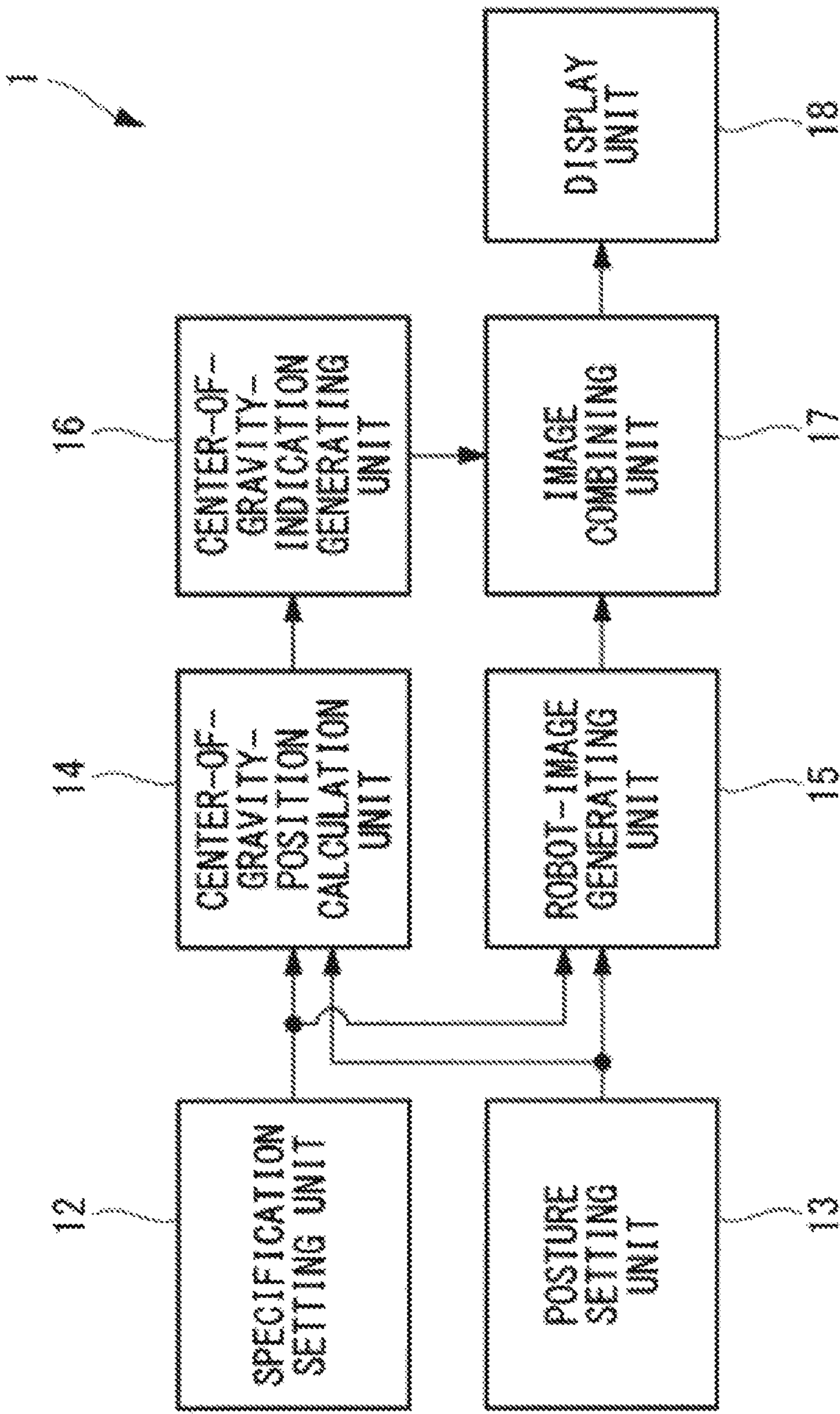


FIG. 3



ROBOT INSTALLATION ANGLE	<input type="text"/>	deg
J1 (X)	<input type="text"/>	deg (mm)
J2 (Y)	<input type="text"/>	deg (mm)
J3 (Z)	<input type="text"/>	deg (mm)
J4 (W)	<input type="text"/>	deg
J5 (P)	<input type="text"/>	deg
J6 (R)	<input type="text"/>	deg
LOAD SETTING NUMBER	<input type="text"/>	
CONVERSION		 REVERSE- CONVERSION
CENTER-OF-GRAVITY POSITION (X, Y, Z) = (xxxx, xxxx, xxxx)		

FIG. 4

GROUP 1		1/10		1/8	
No. LOAD WEIGHT [kg]	COMMENT		GROUP 1		
1	7.80 [HAND	]	1 CONDITION No [ 1 ]: [HAND		
2	70.00 [	]	2 LOAD WEIGHT	[kg]	7.80
3	70.00 [	]	3 CENTER-OF-GRAVITY X [cm]		10.00
4	70.00 [	]	4 CENTER-OF-GRAVITY Y [cm]		0.00
5	70.00 [	]	5 CENTER-OF-GRAVITY Z [cm]		5.00
6	70.00 [	]	6 INERTIA OF LOAD X [kgfoms~2]		0.00
7	70.00 [	]	7 INERTIA OF LOAD Y [kgfoms~2]		0.00
8	70.00 [	]	8 INERTIA OF LOAD Z [kgfoms~2]		0.00
9	70.00 [	]			
10	70.00 [	]			
SELECTED LOAD SETTING NUMBER = 1					

FIG. 5

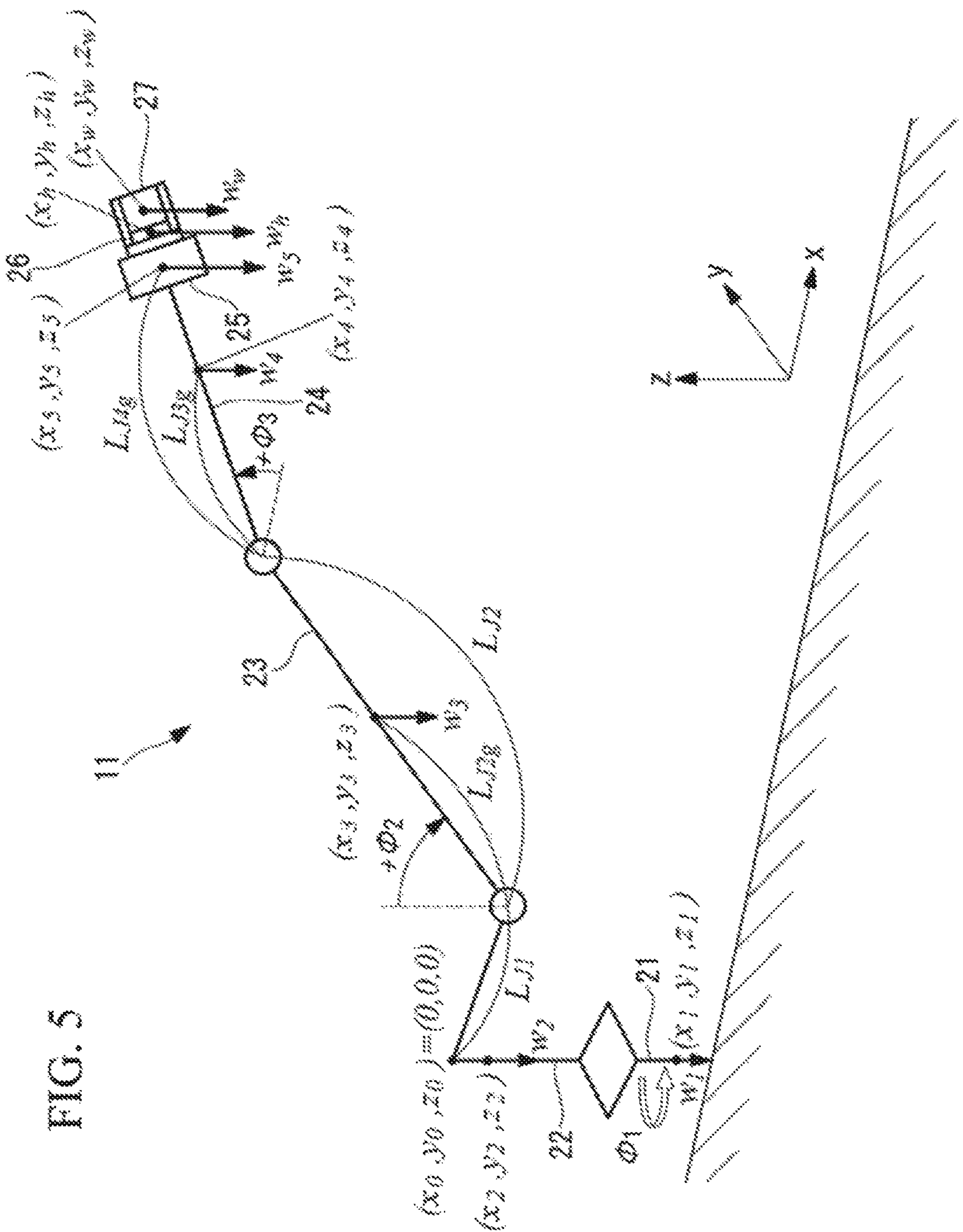




FIG. 6

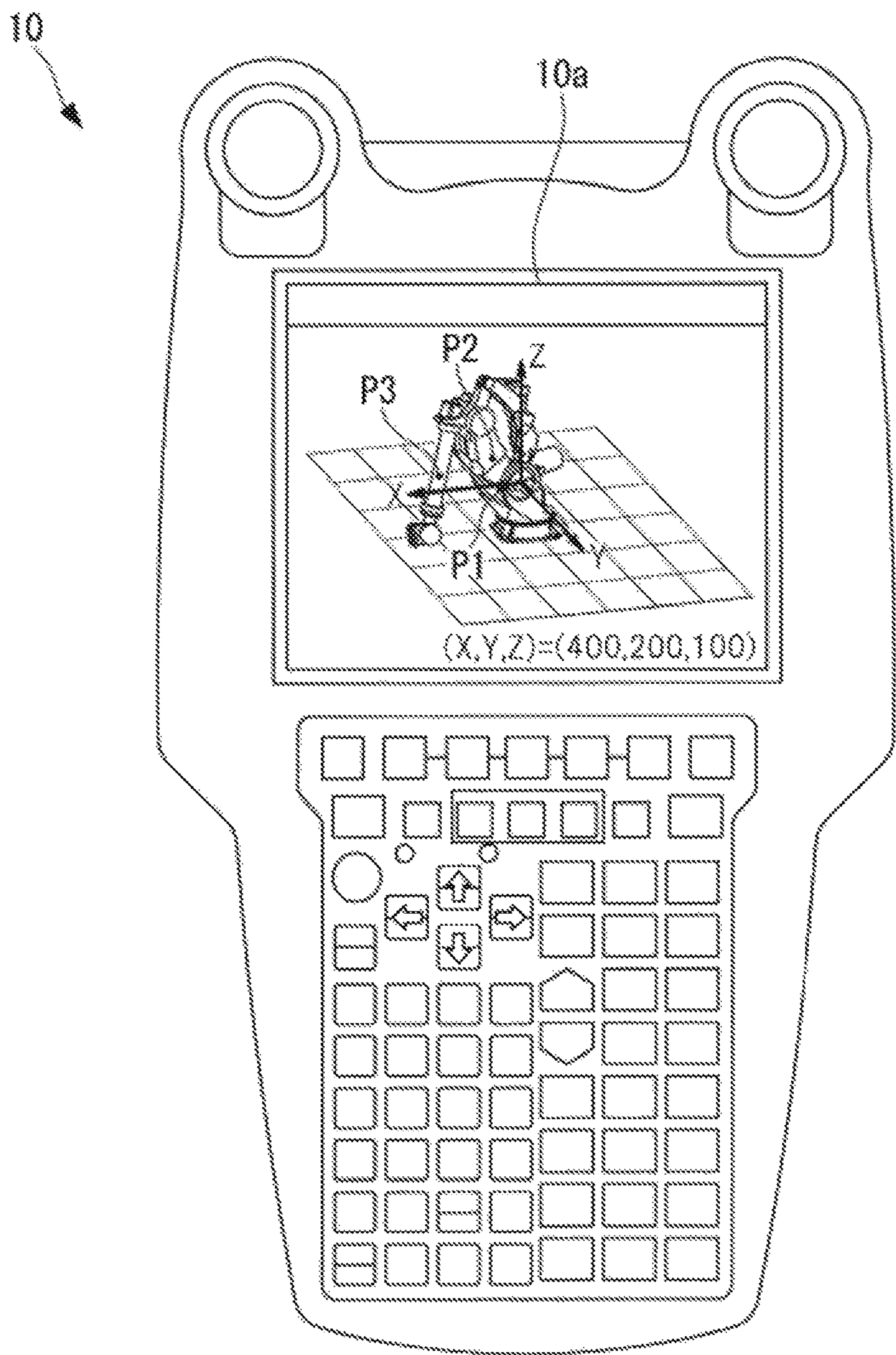
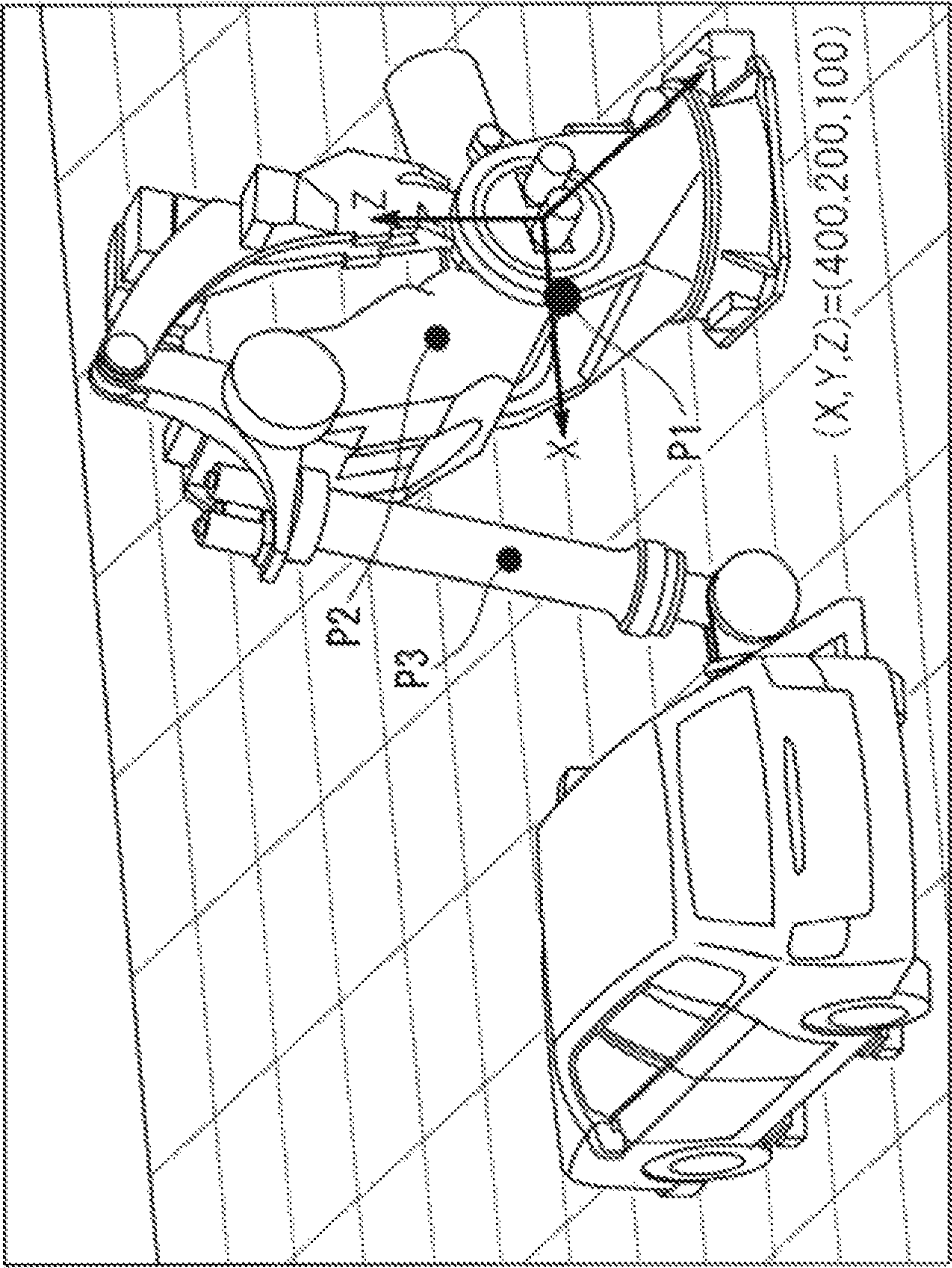




FIG. 7





## 1

# ROBOT CENTER-OF-GRAVITY DISPLAY DEVICE, ROBOT CONTROL DEVICE, AND ROBOT SIMULATION DEVICE

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on Japanese Patent Application No. 2016-137349, the content of which is incorporated herein by reference.

## TECHNICAL FIELD

The present invention relates to a robot center-of-gravity display device, a robot control device, and a robot simulation device.

## BACKGROUND ART

In the related art, there is a known method for automatically calculating the load weight at the leading end of an arm of an articulated robot and the center-of-gravity position thereof without using a force sensor (for example, see PTL 1).

## CITATION LIST

### Patent Literature

{PTL 1} Japanese Unexamined Patent Application, Publication No. Hei 10-138187

## SUMMARY OF INVENTION

The present invention provides the following solutions.

An aspect of the present invention provides a robot center-of-gravity display device including: a specification setting unit that sets the specifications including, at least, the weights, center-of-gravity positions, and dimensions of components of respective shafts of a robot; a posture setting unit that sets position information of the respective shafts of the robot; a robot-image generating unit that generates a three-dimensional model image of the robot in a state in which the respective shafts thereof are located at the positions indicated by the position information on the basis of the position information of the respective shafts of the robot set by the posture setting unit and the specifications of the components set by the specification setting unit; a center-of-gravity-position calculation unit that calculates the center-of-gravity position of the overall robot on the basis of the position information of the respective shafts of the robot set by the posture setting unit and the specifications of the components set by the specification setting unit; an image combining unit that superimposes an indication showing the center of gravity of the overall robot on the three-dimensional model image generated by the robot-image generating unit, at the center-of-gravity position calculated by the center-of-gravity-position calculation unit; and a display unit that displays the image generated by the image combining unit.

Another aspect of the present invention provides a robot control device including any one of the above-described robot center-of-gravity display devices.

Another aspect of the present invention provides a robot simulation device including any one of the above-described robot center-of-gravity display devices.

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## BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a block diagram showing a robot control device including a robot center-of-gravity display device according to an embodiment of the present invention.

FIG. 2 is a functional block diagram showing the center-of-gravity display device in FIG. 1.

FIG. 3 is a diagram showing an example of an input screen of a posture setting unit of the center-of-gravity display device in FIG. 2.

FIG. 4 is a diagram showing an example of information about the weight and center-of-gravity position of a load, stored in association with a load setting number in FIG. 3.

FIG. 5 is a schematic view of a robot for explaining an example center-of-gravity calculation method employed by a center-of-gravity-position calculation unit of the center-of-gravity display device in FIG. 1.

FIG. 6 is a diagram showing an example image generated by an image combining unit of the center-of-gravity display device and displayed on the display unit in FIG. 1.

FIG. 7 is a diagram showing an example indication of the center-of-gravity position in a robot simulation device.

## DESCRIPTION OF EMBODIMENTS

A robot center-of-gravity display device 1 according to an embodiment of the present invention will be described below with reference to the drawings.

The robot center-of-gravity display device 1 according to this embodiment is provided in a robot control device 100.

As shown in FIG. 1, the robot control device 100 includes a CPU 2, a bus 3 connected to the CPU 2, and a ROM 4, a RAM 5, a non-volatile memory 6, a teaching-operation-panel interface (I/F) 7, a shaft control circuit 8, and a center-of-gravity display control unit 9 that are connected in parallel to the bus 3.

A teaching operation panel 10 is connected to the teaching-operation-panel interface 7. The teaching operation panel 10 has a display function. By manually operating the teaching operation panel 10, an operator generates, corrects, and records an operating program for the robot 11, sets various parameters, reproduces a taught operating program, performs jog feeding, etc.

A system program for supporting the basic functions of the robot 11 and the robot control device 100 is stored in the ROM 4. Furthermore, operating programs for the robot 11 that are taught according to the applications and the associated setting data are stored in the non-volatile memory 6. Data, such as programs for various processing, is also stored in the non-volatile memory 6.

As shown in FIG. 2, the center-of-gravity display device 1 according to this embodiment includes: a specification setting unit 12 that sets the specifications including the weights, center-of-gravity positions, and dimensions of components of the respective shafts of the robot 11; a posture setting unit 13 that sets position information of the respective shafts of the robot 11; a center-of-gravity-position calculation unit 14 that calculates the center-of-gravity position of the overall robot 11; a robot-image generating unit 15 that generates a three-dimensional model image of the robot 11; a center-of-gravity-indication generating unit 16 that generates a center-of-gravity-point indication; an image combining unit 17 that superimposes the center-of-gravity-point indication on the three-dimensional model image; and a display unit 18 that displays the combined image.

The specification setting unit 12 is formed of the non-volatile memory 6 shown in FIG. 1. More specifically, the



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specifications are set as a result of the data on the length, weight, and center-of-gravity position of the respective link members, serving as the components constituting the respective shafts of the robot **11**, being stored in the non-volatile memory **6**.

The posture setting unit **13** is formed of the teaching operation panel **10** shown in FIG. **1**. More specifically, the posture setting unit **13** sets the position information of the respective shafts by allowing a user to input the angle information of the respective shafts via the teaching operation panel **10**. When the posture setting unit **13** allows the user to input the angle information of the respective shafts, for example, it displays an indication as shown in FIG. **3** on a display **10a** of the teaching operation panel **10** and allows the user to input the installation angle of the robot **11**, the angles of the respective shafts, and the load setting numbers.

The load setting numbers are the numbers allocated to the respective types of workpieces (loads), hands (components), etc. attached to the leading end or the like of the robot **11**. As shown in FIG. **4**, the load setting numbers are stored in the non-volatile memory **6** so as to be associated with the load weights, center-of-gravity positions, etc., and, when a user inputs a load setting number, the associated load weight and center-of-gravity position can be read.

The center-of-gravity-position calculation unit **14**, the robot-image generating unit **15**, the center-of-gravity-indication generating unit **16**, and the image combining unit **17** are formed of the CPU **2** and the ROM **4**.

The center-of-gravity display control unit **9** is activated when a user inputs a center-of-gravity displaying instruction via the teaching operation panel **10**. Then, the center-of-gravity display control unit **9** displays an input screen, as shown in FIG. **3**, on the display **10a** of the teaching operation panel **10** to allow the user to input information, and reads the component weight and center-of-gravity position data from the non-volatile memory **6** constituting the specification setting unit **12**.

The robot-image generating unit **15** is configured such that the center-of-gravity display control unit **9** causes the CPU **2** to generate a three-dimensional model image of the robot **11** by using a robot-image generating program stored in the ROM **4**, on the basis of the input information about the angles of the respective shafts and the read lengths of link members of the components.

The center-of-gravity-position calculation unit **14** is configured such that the center-of-gravity display control unit **9** causes the CPU **2** to calculate the center-of-gravity position of the overall robot **11** by using a center-of-gravity calculation program stored in the ROM **4**, on the basis of the read component weight and center-of-gravity position data, the input information about the angles of the respective shafts, etc.

An example center-of-gravity position calculation method employed by the center-of-gravity-position calculation unit **14** will be described with reference to Expression 1 and FIG. **5**, by taking a three-axis robot **11** having five units (components) **21**, **22**, **23**, **24**, and **25** and a hand **26** and a workpiece **27** attached at the leading end as an example. The center-of-gravity position of the overall robot **11** can be calculated using Expression 1.

$$x_g = \left( \sum_{i=m}^n w_i x_i + w_h x_h + w_w x_w \right) / \left( \sum_{i=m}^n w_i + w_h + w_w \right) \quad \{\text{Expression 1}\}$$

## 4

-continued

( $m \leq n$   $m$  and  $n$  are natural numbers)

$$y_g = \left( \sum_{i=m}^n w_i y_i + w_h y_h + w_w y_w \right) / \left( \sum_{i=m}^n w_i + w_h + w_w \right)$$

( $m \leq n$   $m$  and  $n$  are natural numbers)

$$z_g = \left( \sum_{i=m}^n w_i z_i + w_h z_h + w_w z_w \right) / \left( \sum_{i=m}^n w_i + w_h + w_w \right)$$

( $m \leq n$   $m$  and  $n$  are natural numbers)

In Expression 1,

$w_n$ : the weight of the  $n$ -th unit,

$w_h$ : the weight of the hand **26**,

$w_w$ : the weight of the workpiece **27**,

$x_g$ : the x coordinate of the center-of-gravity position of the overall robot **11**, based on the x coordinate,  $x_0$ , of the origin of the robot **11**,

$y_g$ : the y coordinate of the center-of-gravity position of the overall robot **11**, based on the y coordinate,  $y_0$ , of the origin of the robot **11**,

$z_g$ : the z coordinate of the center-of-gravity position of the overall robot **11**, based on the z coordinate,  $z_0$ , of the origin of the robot **11**,

$x_n$ : the x coordinate of the center-of-gravity position of the  $n$ -th unit, based on the x coordinate,  $x_0$ , of the origin of the robot **11**,

$y_n$ : the y coordinate of the center-of-gravity position of the  $n$ -th unit, based on the y coordinate,  $y_0$ , of the origin of the robot **11**,

$z_n$ : the z coordinate of the center-of-gravity position of the  $n$ -th unit, based on the z coordinate,  $z_0$ , of the origin of the robot **11**,

$x_h$ : the x coordinate of the center-of-gravity position of the hand **26**, based on the x coordinate,  $x_0$ , of the origin of the robot **11**,

$y_h$ : the y coordinate of the center-of-gravity position of the hand **26**, based on the y coordinate,  $y_0$ , of the origin of the robot **11**,

$z_h$ : the z coordinate of the center-of-gravity position of the hand **26**, based on the z coordinate,  $z_0$ , of the origin of the robot **11**,

$x_w$ : the x coordinate of the center-of-gravity position of the workpiece **27**, based on the x coordinate,  $x_0$ , of the origin of the robot **11**,

$y_w$ : the y coordinate of the center-of-gravity position of the workpiece **27**, based on the y coordinate,  $y_0$ , of the origin of the robot **11**, and

$z_w$ : the z coordinate of the center-of-gravity position of the workpiece **27**, based on the z coordinate,  $z_0$ , of the origin of the robot **11**.

Furthermore, because the first unit **21** is fixed to the ground, and the center-of-gravity position thereof does not change, the coordinates ( $x_1$ ,  $y_1$ ,  $z_1$ ) of the center-of-gravity position of the first unit **21** based on the origin ( $x_0$ ,  $y_0$ ,  $z_0$ ) of the robot **11** are expressed as:

$$x_1 = L1gx;$$

$$y_1 = L1gy; \text{ and}$$

$$z_1 = L1gz,$$

by using the x, y, and z components (L1gx, L1gy, and L1gz) of the distance based on the origin of the robot **11**.

The second unit **22** is rotated by the first unit **21** about the vertical axis, at a rotation angle  $\varphi_1$ . Hence, the coordinates



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( $x_2, y_2, z_2$ ) of the center-of-gravity position of the second unit **22** based on the origin ( $x_0, y_0, z_0$ ) of the robot **11** are expressed as:

$$x_2 = L_{2gx} \cos \varphi_1;$$

$$y_2 = L_{2gy} \sin \varphi_1; \text{ and}$$

$$z_2 = L_{2gz},$$

by using the x, y, and z components ( $L_{2gx}$ ,  $L_{2gy}$ , and  $L_{2gz}$ ) of the distance based on the origin of the robot **11**.

The coordinates of the center-of-gravity positions of the third, fourth, and fifth units **23**, **24**, and **25** are:

$$x_3 = (L_{J1} + L_{J2g} \sin \varphi_2) \cos \varphi_1;$$

$$y_3 = (L_{J1} + L_{J2g} \sin \varphi_2) \sin \varphi_1;$$

$$z_3 = L_{J2g} \cos \varphi_2;$$

$$x_4 = (L_{J1} + L_{J2} \sin \varphi_2 + L_{J3g} \cos \varphi_3) \cos \varphi_1;$$

$$y_4 = (L_{J1} + L_{J2} \sin \varphi_2 + L_{J3g} \cos \varphi_3) \sin \varphi_1;$$

$$z_4 = L_{J2} \cos \varphi_2 + L_{J3g} \sin \varphi_3;$$

$$x_5 = (L_{J1} + L_{J2} \sin \varphi_2 + L_{J4g} \cos \varphi_3) \cos \varphi_1;$$

$$y_5 = (L_{J1} + L_{J2} \sin \varphi_2 + L_{J4g} \cos \varphi_3) \sin \varphi_1; \text{ and}$$

$$z_5 = L_{J2} \cos \varphi_2 + L_{J4g} \sin \varphi_3.$$

Herein,

$L_{J1}$ : the offset between the center of rotation of the first unit **21** and the center of rotation of the second unit **22**;

$L_{J2}$ : the length of a link that is swung in the vertical direction by the second unit **22**;

$L_{J2g}$ : the distance between the center of rotation of the second unit **22** and the center-of-gravity position of the second unit **22**;

$L_{J3g}$ : the distance between the center of rotation of the third unit **23** and the center-of-gravity position of the third unit **23**;

$L_{J4g}$ : the distance between the center of rotation of the third unit **23** and the center-of-gravity position of the fourth (wrist) unit **24**;

$\varphi_2$ : the rotation angle of the second unit **22** about the horizontal axis; and

$\varphi_3$ : the rotation angle of the third unit **23** about the horizontal axis.

The coordinates of the center-of-gravity position of the overall robot **11** can be calculated with Expression 1 by assuming that  $n=1$  and  $m=5$ , and the coordinates of the center-of-gravity position of the second unit **22** alone can be calculated with Expression 1 by assuming that  $n=m=2$ . Furthermore, the coordinates of the center-of-gravity position of a complex unit composed of the second and third units **22** and **23** can be calculated with Expression 1 by assuming that  $n=2$  and  $m=3$ .

The center-of-gravity-position calculation unit **14** calculates and displays the center-of-gravity position on the display **10a** when, for example, information about the angles of the respective shafts and the load setting numbers are input in the input screen in FIG. 3, and then a conversion arrow is designated. As shown in FIG. 3, a reverse-conversion arrow may be provided. With this configuration, by designating the reverse-conversion arrow after inputting the load setting numbers and the center-of-gravity position, the position information of the respective shafts may be obtained by reverse conversion.

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The center-of-gravity-indication generating unit **16** is configured such that the center-of-gravity display control unit **9** causes the CPU **2** to generate a center-of-gravity indication image in which, for example, a preliminarily stored image of a sphere or the like is disposed at the center-of-gravity position of the overall robot **11** that has been calculated by the center-of-gravity-position calculation unit **14**.

The image combining unit **17** is configured such that the center-of-gravity display control unit **9** causes the CPU **2** to combine the three-dimensional model image of the robot **11** that has been generated by the robot-image generating unit **15** and the center-of-gravity indication image that has been generated by the center-of-gravity-indication generating unit **16** and disposed at the center-of-gravity position of the overall robot **11** to generate a combined image.

Then, the combined image generated by the CPU **2** is sent to the teaching operation panel **10**, via the teaching-operation-panel interface **7**, by the center-of-gravity display control unit **9** and is displayed on the display **10a** of the teaching operation panel **10**, as shown in FIG. 6.

According to the thus-configured robot center-of-gravity display device **1** according to this embodiment, a user can, simply by inputting information about the angles of the respective shafts with which a posture of the robot **11** about which he/she wants to check the center-of-gravity position is achieved and then selecting a load, easily and intuitively check an image in which an indication showing the center of gravity is superimposed on a three-dimensional model image of the robot **11** that assumes that posture, on the display **10a**. Accordingly, it is possible to determine the center-of-gravity position of the robot **11** when the robot **11** is transported or when construction of a robot system is considered, leading to an advantage in that it is possible to prevent the robot **11** from falling over etc.

Furthermore, as described above, by inputting the installation angle of the robot **11**, even when the robot **11** is installed in an inclined manner, it is possible to calculate the center-of-gravity position by taking the installation angle into account.

Note that, in this embodiment, although an example case where the specification setting unit **12** is formed of the non-volatile memory **6** has been described, the user may input information from the teaching operation panel **10**.

Furthermore, although the posture setting unit **13** allows the user to input information from the teaching operation panel **10**, instead of this, information about the angles of the respective shafts in the respective steps of the robot operating program designated by the user may be read and then configured in a chronological order.

More specifically, every time the information about the angles of the respective shafts in each step is read from the robot operating program, a three-dimensional model image of the robot **11** is generated by the robot-image generating unit **15**, the center-of-gravity position of the overall robot **11** is calculated by the center-of-gravity-position calculation unit **14**, an indication of the center of gravity is generated by the center-of-gravity-indication generating unit **16**, and images are combined by the image combining unit **17** and displayed on the display unit **18**. As a result, the three-dimensional model image of the robot **11** moves like a frame-by-frame image or video, and the center-of-gravity position in each posture also moves with the movement of the three-dimensional model image. Thus, there is an advantage in that the user can easily and intuitively determine changes of the center-of-gravity position during the operation of the robot **11**.



In this embodiment, although the center-of-gravity-indication generating unit 16 generates a spherical indication showing the center of gravity at the center-of-gravity position, the shape of the indication is not limited to spherical, but may be any shape. Furthermore, in addition to the spherical or other indication of the center of gravity, as shown in FIG. 6, the coordinate values of the center of gravity may be indicated by text. By doing so, a user can more accurately check the position of the center of gravity.

In this embodiment, although the center of gravity of the overall robot 11 is displayed, in addition to this, as shown in, for example, FIG. 6, center-of-gravity positions P1, P2, and P3 of the units 21, 22, 23, 24, and 25 of the respective shafts may be displayed.

In this embodiment, although a case where the robot control device 100 is provided with the center-of-gravity display device 1 has been described, instead of this, the center-of-gravity display device 1 may be provided in a simulation device that is not connected to the robot 11. By doing so, as shown in FIG. 7, the present invention can be used in a case where the center-of-gravity positions P1, P2, and P3 in the respective postures of the robot 11 are simulated, when a large load (for example, a car or a hand for handling the car) or the like that is difficult to prepare is assumed.

As a result, the above-described embodiment leads to the following aspects.

An aspect of the present invention provides a robot center-of-gravity display device including: a specification setting unit that sets the specifications including, at least, the weights, center-of-gravity positions, and dimensions of components of respective shafts of a robot; a posture setting unit that sets position information of the respective shafts of the robot; a robot-image generating unit that generates a three-dimensional model image of the robot in a state in which the respective shafts thereof are located at the positions indicated by the position information on the basis of the position information of the respective shafts of the robot set by the posture setting unit and the specifications of the components set by the specification setting unit; a center-of-gravity-position calculation unit that calculates the center-of-gravity position of the overall robot on the basis of the position information of the respective shafts of the robot set by the posture setting unit and the specifications of the components set by the specification setting unit; an image combining unit that superimposes an indication showing the center of gravity of the overall robot on the three-dimensional model image generated by the robot-image generating unit, at the center-of-gravity position calculated by the center-of-gravity-position calculation unit; and a display unit that displays the image generated by the image combining unit.

According to this aspect, once the specification setting unit sets the specifications including the weights, center-of-gravity positions, and dimensions of the components of the robot, and the posture setting unit sets the position information of the respective shafts of the robot, the robot-image generating unit generates a three-dimensional model image of the robot in a state in which the respective shafts thereof are located at the positions indicated by the position information. Then, the center-of-gravity-position calculation unit calculates the center-of-gravity position of the overall robot on the basis of the position information of the respective shafts of the robot and the specifications of the components, and the image combining unit generates an image in which an indication showing the center of gravity of the overall robot is superimposed on the generated three-dimensional

image of the robot, at the center-of-gravity position. Then, this image is displayed on the display unit. With this configuration, regardless of the posture of the robot, the user can easily and intuitively determine the center-of-gravity position of the robot through the image displayed on the display unit.

In the above aspect, the indication showing the center of gravity may include coordinate values showing the center-of-gravity position of the overall robot.

With this configuration, by displaying the coordinate values showing the center-of-gravity position of the overall robot, the user can more clearly determine the center-of-gravity position of the robot.

Furthermore, in the above aspect, the center-of-gravity-position calculation unit may calculate the center-of-gravity positions of the respective components, and the image combining unit may superimpose indications showing the centers of gravity of the respective components on the three-dimensional model image, at the center-of-gravity positions of the respective components.

With this configuration, the user can easily and intuitively determine the center-of-gravity positions of the respective components, in addition to the center-of-gravity position of the overall robot.

Furthermore, in the above aspect, the components may include a load attached to the leading end of the robot.

With this configuration, the load attached to the leading end of the robot is treated as a part of the components of the robot, thus enabling the user to easily determine the center-of-gravity position of the overall robot including the load.

Furthermore, in the above aspect, the posture setting unit may read multiple sets of position information of the respective shafts of the robot recorded in an operation program of the robot and may configure the position information in a chronological order.

With this configuration, when the respective shafts of the robot move so as to assume a plurality of postures in a chronological order in accordance with the operation program of the robot, as a result of the posture setting unit setting position information of the respective shafts at different times, the robot-image generating unit generates three-dimensional model images of the robot at these times, the center-of-gravity-position calculation unit calculates the center-of-gravity positions of the overall robot at these times, and images in which an indication of the center of gravity is superimposed on the three-dimensional model image are generated.

As a result, by displaying the thus-generated plurality of images so as to be switched from one to another in a chronological order, the three-dimensional model image of the robot moves like a frame-by-frame image or video, and the center-of-gravity position in each posture also moves with the movement of the three-dimensional model image. With this configuration, the user can easily and intuitively determine changes of the center-of-gravity position during the operation of the robot.

Furthermore, in the above aspect, the position information of the respective shafts of the robot may include the installation angle of the robot.

With this configuration, even if the robot is installed in an inclined manner, it is possible to calculate the center-of-gravity position, taking the installation angle into account.

Another aspect of the present invention provides a robot control device including any one of the above-described robot center-of-gravity display devices.



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Another aspect of the present invention provides a robot simulation device including any one of the above-described robot center-of-gravity display devices.

The present invention provides an advantage in that it enables a user of a robot to easily determine the center-of-gravity position of the robot.

## REFERENCE SIGNS LIST

- 1 center-of-gravity display device
- 2 CPU (center-of-gravity-position calculation unit, robot-image generating unit, center-of-gravity-indication generating unit, and image combining unit)
- 4 ROM (center-of-gravity-position calculation unit, robot-image generating unit, center-of-gravity-indication generating unit, and image combining unit)
- 6 non-volatile memory (specification setting unit)
- 10 teaching operation panel (posture setting unit)
- 11 robot
- 12 specification setting unit
- 13 posture setting unit
- 14 center-of-gravity-position calculation unit
- 15 robot-image generating unit
- 17 image combining unit
- 18 display unit
- 21, 22, 23, 24, and 25 unit (component)
- 26 hand (component)
- 27 workpiece (component and load)
- 100 robot control device

The invention claimed is:

1. A robot center-of-gravity display device comprising:
  - a specification setting unit that stores specifications set in advance, the specifications including, at least, the weights, center-of-gravity positions, and dimensions of components of respective shafts of a robot;
  - a posture setting unit in which position information of the respective shafts of the robot is set on a basis of designation by a user;
  - a robot-image generating unit that generates a three-dimensional model image of the robot in a state in which the respective shafts thereof are located at the positions indicated by the position information based on the position information of the respective shafts of the robot set by the posture setting unit and the speci-

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fications of the components of the respective shafts of the robot set by the specification setting unit;

- a center-of-gravity-position calculation unit that calculates the center-of-gravity position of the overall robot based on the position information of the respective shafts of the robot set by the posture setting unit and the specifications of the components of the respective shafts of the robot set by the specification setting unit;
- an image combining unit that superimposes an indication showing the center of gravity of the overall robot on the three-dimensional model image generated by the robot-image generating unit, at the center-of-gravity position calculated by the center-of-gravity-position calculation unit; and
- a display unit that displays the image generated by the image combining unit.

2. The robot center-of-gravity display device according to claim 1, wherein the indication showing the center of gravity includes coordinate values showing the center-of-gravity position of the overall robot.

3. The robot center-of-gravity display device according to claim 1, wherein

the center-of-gravity-position calculation unit calculates the center-of-gravity positions of the components of the respective shafts of the robot, and

the image combining unit superimposes indications showing the centers of gravity of the components of the respective shafts of the robot on the three-dimensional model image, at the center-of-gravity positions of the components of the respective shafts of the root.

4. The robot center-of-gravity display device according to claim 1, wherein the components include a load attached to a leading end of the robot.

5. The robot center-of-gravity display device according to claim 1, wherein the posture setting unit reads multiple sets of position information of the respective shafts of the robot recorded in an operating program of the robot and configures the position information in a chronological order.

6. The robot center-of-gravity display device according to claim 1, wherein the position information of the respective shafts of the robot includes the installation angle of the robot.

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